Soybean Proteins in Prudent-Diet Foods

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ABSTRACT

A review is presented on soybean proteins and their health, nutritional, convenience, stability, and economic attributes that justify usage in prudent-diet foods. The concept of these foods is discussed with consideration the contributions of soybean proteins to caloric energy, ratios of polyunsaturated to saturated fatty acids, cholesterol, sodium ion, and levels of sugars. Soybean proteins provide technologists with a cheap, functional protein source for developing meat analogs. Inherent soybean flavors are considered the major unstabilizing problem in prudent-diet foods. The energy requirement for producing one pound of meat analog is estimated at 12,300 BTU; soy flour used in it requires only 330 BTU, while cooked meat requires approximately 52,250 BTU per pound.

INTRODUCTION

Alex Osborn in his book *Your Creative Power,* (1) stated, "Creative research is packed with questions like, How about? ... What if? ... What else? ... at the end come the questions, Will it work? ... Can it be made commercially?" I should add to this, "Will the consumer advocates and regulatory agencies accept it?" "Does it have Achilles Heels to kill it and bury it alive?" Of course, what this prelude is all about is a summation to why we are all here. It was creative imagination to take the lowly soybean meal and refine it to make a rich source of protein. Creative research guided the workers who thought, "How about making muscle-like fibers from soy proteins?" and those who followed the idea, "What if we extrude the soy protein in a plastic or rubber extruder to make a mass of muscle-like structure and texture?" The answer in all cases was, "It worked," and it was the birth of new technology in food processing.

I attended a symposium on "Developing Foods for the Cardiac Concerned" at the 33rd Annual Meeting of the Institute of Food Technologists in June 1973 in which the "prudent-diet" term was explained by Livingston (2) as "the diet recommended by the Bureau of Nutrition of the New York City Health Department to test the hypothesis that man who follow a diet designed to reduce serum cholesterol experience a lower rate of coronary incidents than those who consume a typical American diet." What are the health/nutrition aspects in prudent-diet foods? Table I shows the daily intake limits of fat, cholesterol, salt, and refined simple sugars as recommended by the Bureau of Nutrition. The fatty acid ratio of polyunsaturated/monounsaturated/saturated also directly or indirectly affects the coronary incidents so that the high ratio of saturated fatty acids (above 1.0), as found in animal sources, increases the rate of coronary attacks.

We should like to expand the concept of prudent-diet foods in this text to cover health threats, other than coronary, that cause chronical organic diseases. For example, maximum intake of nonprotein nitrogen should be considered because of the burden imposed on the kidneys to rid the body from their metabolic breakdown products. Fiber should also be included because of its role in vitamin/mineral absorption, in reducing the toxicity of ingested heavy metals, and in absorption of cholesterol (3).

Why should we encourage the concept of prudent-diet foods? Those who can restrict their weekly consumption to four eggs, four 4-ounce portions of meat, low-fat ice cream, and cheese in moderation (4) (whatever this means) will reduce the risk of coronary attack. But we know that when restrictions are imposed, particularly on foods we love, food becomes an obsession and some will eat themselves to death. When we examine in Table II per capita consumption of proteins and fats from animal sources, one observes the shifts in consumption pattern from dairy (except cheese) and eggs to meats, but fat in total intake reached 40.5% of the daily diet.

Prudent-diet foods allow the consumption of satisfying quantities of foods we like without the high risk of coronary incidents. We do not have to keep a diary and a calculator at the dining table to record the permissible quantities of food we should eat, assuming that the contents of each food item are known.

The pieces needed to develop an engineered food are available, particularly for animal products such as meat and dairy. Furthermore, these foods can be produced at economically reasonable, if not cheap, costs because they are composed of commodities such as soybean oil and proteins.

Animal and diary scientists have not given up on increasing the ratio of unsaturated to saturated fatty acids in meat and dairy herds. Tracey (5) and Scott (6) in Australia studied the effects of increasing the polyunsaturated fatty acids in ruminant meat and dairy products. Tracey (5) succeeded in increasing the polyunsaturated fatty acids in meat and milk fats by feeding a supplement composed of sunflower seed and soybean at a 70:30 ratio but encountered the problems of loss in flavor quality and high susceptibility to autoxidation. Therefore, this innovative approach has some way to go.

The road to fabricate direct substitutes or engineered foods has not been without problems either. Some of these problems are related to the technologies at hand, and a few are caused by the inherent characteristics in soybean proteins.

Three problems hinder soybean proteins from reaching potential use in food products. At the top is the presence of undesirable flavors which generate during processing soy-

TABLE I

Health/Nutrition Aspects in Prudent-Diet Foods

Food component	Daily intake
Caloric intake from fat	35.0% max.
Polyunsaturates/monounsaturates/saturates	1:1:1
Cholesterol	300 mg max.
Salt (NaCl)	5.0 g max.
Complex/simple refined carbohydrate	Highest practical ratio
Calorie intake from protein	15.0-20.0%

TABLE II

Per Capita Consumption of Fats and Proteins in Pounds from Animal Sources[a]

Category	Year 1960 lbs.	Year 1974 lbs.	% Change
Meats	160.9	186.2	+ 15.7
Fish	10.3	12.5	+ 2.1
Eggs (number)	(334.0)	(285.2)	− 14.6
Turkey	6.1	9.4	+ 54.1
Cheese	8.3	14.7	+ 77.1
Milk and cream	322.0	248.6	− 22.8
Ice cream	18.3	17.7	− 3.3
Butter	7.5	4.3	− 42.7
Margarine	9.4	11.8	+ 25.5

[a]See Reference 5.

TABLE III

Nutritional and Health Aspects in 100 g of Soybean Isolated Proteins, Full-fat or Defatted Flours

Nutrient or parameter	Soy isolates	Full-fat flour	Defatted flour
Calories	360.0-392.0	350.0-400.0	273.0-295.0
Protein, g	90.0-97.7	38.5-43.0	51.0-55.0
Fat, g	0.2-1.2	19.1-23.0	1.0-3.5
PU/MUS/S[a]	-	3:1:1	3:1:1
Cholesterol, mg	none	none	none
Sucrose, g	-	4.8-6.4	6.0-8.0
Dextrose, g	-	trace	trace to 0.1
Fiber, g	0.25-0.4	2.0-2.3	2.5-3.0
Sodium, g	0.15-1.5	0.2	0.20-0.25

[a]Polyunsaturates, monounsaturates, saturates.

TABLE IV

Biological Value (BV) and Net Protein Utilization (NPU) of TVP® from Soybean Defatted Flour[a]

Protein source	BV	NPU
Meat	43.6	39.3
TVP	35.7	30.9
Deficit in TVP	−18.0%	−21.0%

[a]See Reference 7.

TABLE V

Content of Elements in Unflavored Textured Soy Protein[a]

Element	Content	
	mg/100 g	% RDA[b] in 20 g protein
Calcium	252.0	10.0
Magnesium	302.0	30.2
Phosphorus	740.0	29.6
Iron	9.6	21.0
Copper	1.6	32.0
Zinc	5.6	14.9
Iodine	trace	<1.0
Cobalt	trace	-
Manganese	3.6	-
Boron	3.8	-
Aluminum	0.9	-

[a]See Reference 9.

[b]Recommended daily allowance.

bean protein-containing products. Thermoplastic extrusion and commercial canning operations reveal these undesirable flavors which are imcompatible with added meat-like or dairy-like analog flavors. A breakthrough is badly needed in this area.

The other two problems are interrelated because they deal with consumers' attitudes concerning analogs including prudent-diet foods. So far, consumers have not accepted ersatz foods made with soybean and other plant proteins and have considered them inferior to the natural products. The lower biological value (BV) and net protein utilization (NPU) in soybean vs. animal proteins is partially responsible for consumers' lack of interest.

SOYBEAN PROTEINS AND ATTRIBUTES OF PRUDENT-DIET FOODS

What has made soybean proteins a major building block in prudent-diet foods? We can answer this question in light of the desirable attributes in these foods, and the nutritional/functional/economical aspects of soybean proteins. The attributes observed by food technologists and marketing managers in prudent-diet foods are: (a) safety—to secure satisfactory nutrition and health; (b) palatability—to bring about similar enjoyment to that in eating familiar foods; (c) convenience in preparation requirements and time; (d) shelf life to minimize waste in distribution channels and cost to consumer; (e) economy so that cost/value is meaningful to the consumer.

The aspects of safety, nutrition, and health are of paramount importance in prudent-diet foods, and obviously soybean proteins must be examined in regard to these qualities. Table III contains components or parameters in soybean isolates and full-fat and defatted flours that relate to prudent-diet foods guidlines mentioned in Table I. Generally, the caloric energy of these soybean protein products does not exceed 4.0 calories/g. Oil in full-fat flour contributes ca. 50% of the caloric energy while it is negligible in soy isolates and defatted flour. The ratio of polyunsaturated to mono-unsaturated to saturated fatty acids is ca. 3:1:1 which allows flexibility to mix with fats of higher levels of saturated fatty acids and still achieve the desirable 1:1:1 ratio. Obviously, soy isolates and defatted soy flours allow maximum flexibility to develop products with the required fatty acid ratio.

The significance of no cholesterol is self evident. Sucrose and dextrose are present at low levels in full-fat and defatted flours which do not interfere in developing the required balance of nutrients; however, it should be noted that these ingredients contain raffinose and stachyose which contribute to flatulence.

The presence of fibers at these low levels can be an advantage as discussed earlier. Finally, sodium levels expressed on protein basis range from 0.4 mg/g to 1.5 mg/g of protein which is an acceptable range to work with and meet the maximum salt intake requirement.

Nutritional Quality in Soybean Proteins

A cursory look at the major nutrient in soybean proteins is given here to show the magnitude of deficiency in quality. Debry et al. (7) established the biological value (BV) and net protein utilization (NPU) for TVP® and meat by feeding human adults and children. The results in Table IV show those from the study of human adults. Soybean protein in a nitrogen-blance feeding test has ca. 18% deficit in BV and 21% deficit in NPU. Soybean proteins are deficient in all vitamins except for thiamine and folic acid. They are, however, good sources for magnesium, phosphorus, copper, and zinc, as shown in Table V.

The quality deficit inherent in soybean proteins can be corrected by supplementation with proteins of better quality such as egg white, lactalbumin, or fish protein. A better solution is the incorporation of methionine and valine in the protein to improve its biological value to approach that of milk or meat proteins. Supplementation of the finished food with vitamins and minerals to meet the US dietary requirements is the easy way to correct this imbalance.

Hazards from antinutritional factors in soybean proteins such as trypsin inhibitor and phytohemagglutinins were

reviewed by Rackis (8). Heat treatment of soybeans at 100 C for 15 min was found adequate to inactivate these antimetabolites. No aflatoxins or ochratoxins have been detected in soybeans or their products. Levels of heavy metals in textured soy proteins were determined and were found negligible (9).

Palatability

The second attribute required in prudent-diet foods is palatability, which brings about enjoyment in consuming these foods in a manner similar to that enjoyed in eating familiar foods.

Soybean proteins do not contribute to palatability of prudent-diet foods so much as to the undesirable flavors they add, as we discussed earlier. The complexity of flavor problem in soybean protein may be attributed to the interaction of these factors: (a) lipoxygenase and lipase activation during crushing the beans in processing which results in lipid degradation and oxidation products, (b) the heat used during oil extraction with n-hexane. Smith and Circle (10) reviewed the flavor components in soybeans, and the list of isolated chemicals is growing, but understanding of their significance in relation to flavor is not complete.

Convenience

What functional aspects in soybean proteins contribute to the convenience advantage in prudent-diet foods? The first advantage is reducing cooking-time relative to that required in preparing standard foods. For example, Morningstar Farms' Breakfast Strips® bacon analog require 8 min to fry while bacon has to be fried for 20 min to reach a comparable level of crispness. This is understandable since the proteins are gelled during processing of Breakfast Strips, and the frying step just develops the desirable texture and flavor.

The second functional advantage for soybean proteins is their fat and water-holding capacity. Soybean protein isolates, depending on solubility, can bind up to 35% of their weight of vegetable oils and on average bind 18.0%. Therefore, meat analogs do not release fat/moisture during cooking as do the standard products, which can lose up to 70% of their weight in fat drip. An attractive feature of this advantage is packaging prudent-diet foods for serving hot lunches via vending machines and microwave ovens.

Shelf Life Stability

Those knowledgeable in the field of convenience food products realize the number of technical problems encountered in formulating, processing, and packaging such products. Soybean proteins contribute to both stability and instability in the modern food products. The magnitude of instability is dependent on water activity in the food system and on the temperature maintained during the channels of distribution, namely, frozen, refrigerated, and/or ambient conditions. The best combination is water activity below 0.85 and holding the product in the frozen state; the worst is high water activity (above 0.90) and storage at ambient conditions.

What factors in soybean proteins lead to stability and instability of prudent-diet foods? Stabilizing factors in soybean proteins are: (a) water and fat-holding capacity are relatively high: (b) such peroxidants as the heme pigment which accelerates the oxidation of polyunsaturated fatty acids in meat are absent; (c) enzymatic activity is virtually eliminated during processing of soybean proteins; (d) soybean proteins, to a certain extent, bind added flavoring components.

Inherent soybean flavors are the major unstabilizing factor in prudent-diet foods. Microbiological load, particularly *Clostridium perfringens,* can be a source of concern for its role in reducing the shelf life of these foods.

Economy

By far, this is the most encouraging attribute that promotes the sales of prudent-diet foods, and soybean proteins offer a lot in this category. Table VI shows the comparative costs of net utilizable protein (NUP) from animal and plant sources (11). The prices are quoted from 1971 and the figures today are higher; however, the relative positions of protein source/price did not change. It is noteworthy to mention that the competitive forces increased significantly this year where Brazilian soybean production and the surplus of milk protein in European Economic Community (EEC) countries have forced the price of soybean flour down to $0.13/kg.

TABLE VI

Relative Cost of Net Utilizable Protein[a]

Protein source	Price ($/kg)	NUP[b] ($/kg)
Beef	1.08	7.19
Fish	0.99	6.77
Chicken	0.73	5.44
Milk	0.15	5.16
Eggs	0.55	4.61
Rice	0.20	3.77
Cottonseed flour	0.77	3.46
Whey (dry)	0.20	1.85
Skim milk	0.48	1.74
Dry beans	0.15	1.43
Wheat	0.07	0.90
Soybean flour	0.18	0.68

[a]Wholesale lots. FOB point of manufacture.

[b]Net utilizable protein—portion of nitrogen intake retained in the human body.

The obvious conclusion here is that soybean proteins are and will remain the cheapest source of protein for human use.

ENERGY REQUIREMENTS FOR PRUDENT-DIET FOODS

Actually, this is an addendum to the economy aspect we discussed above. The threat of energy shortage is a fact and the status quo drives food processors toward energy conservation. If we consider meat analogs as examples of prudent-diet foods, then we can refer to Henig and Schoen's (12) calculations on energy requirements for the production cycles of fresh meat and a model system of meat analog. The authors estimated energy requirements for one pound of fresh meat at 41,250 BTU, and an additional 10,000 BTU for distribution and cooking. A meat-analog system composed of soy flour, hydrogenated soybean oil, egg albumin, and other ingredients requires 12,300 BTU/lb for the total production cycle. Out of the total of 2,300 BTU/lb of ingredients, soy flour require 330 BTU or ca. 14.0%.

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